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III. *A new Method of assaying Copper Ores.*

By George Fordyce, M. D. F. R. S.

Read Nov. 25, 1779.

## P R O C E S S.

**T**AKE 100 grains of the ore, powder it finely, put it into a small matrafs or a glafs phial, pour upon it half an ounce of nitrous acid, of the strength commonly fold by the name of *aqua fortis*, that is, the pure acid diluted with about four-times its weight of water; and half an ounce of muriatic acid fold by the name of spirit of salt; place the vessel in a sand heat, or if you have none, an iron pot or fire shovel with sand may be put over a common fire, and the matrafs or phial set in it. Raise a moderate heat, an effervescence will take place for the most part; when this ceases increase the heat till it is renewed, and so proceed till the liquor boils, which is also to be done if no effervescence takes place; boil them together for a quarter of an hour.

Remove the vessel from the fire, and let it cool, then pour into it two ounces of water, shake them together,

and let them stand till the liquor is clear; pour the clear liquor into a basin where it may be preserved.

Add to the *residuum* a fresh half ounce of each of the acids, and proceed again in the same manner, mixing the clear liquor with that procured by the first process.

The same operation is to be repeated until the fresh acids acquire no tinge of blue or green.

Dissolve half a pound of mild fixed vegetable alkali, commonly sold by the name of salt of tartar, in a quart of water. Purify the solution either by filtration, or letting the impurities subside, and decanting the liquor clear into a glass vessel. Pour the solution of the alkali slowly into the basin containing the fluid, procured by the former processes, until the whole matter be precipitated from the acids.

Add, by a little at a time, as much vitriolic acid, commonly sold by the name of oil of vitriol, as will redissolve the whole, or only leave a white powder; if there should be any such powder, which is seldom the case, it must be separated by filtration.

Having the liquor in the basin now clear, put into it a piece of iron, bright and free from rust, and at least an ounce in weight, and leave them together for twenty-four hours, the copper will be found precipitated, principally on the surface of the iron, and sometimes in a powder at the bottom of the basin.

Decant

Decant the fluid from the copper and iron with great care into another bafon, fo that as little as poffible or none of the copper be carried along with it.

Wafh the metals in a pint of water; let them fubfide perfectly, and pour this water into the fecond bafon, with the fame care,

Repeat the wafhing three times. If any copper be found in the fecond bafon, let the wafhings ftand in it for half an hour, fo that the metal fhall fubfide; decant the fluid carefully off, and return the copper into the firft bafon. Pour upon the copper and iron one ounce of vitriolic acid, and two ounces of water; let them ftand together for a quarter of an hour, or until the copper fhall be eafily feparable from the iron. Separate the copper from the iron, taking great care none be loft; the remaining iron may be laid afide. Pour the acid from the copper, after it has fubfided, into the fecond bafon, and wafh the copper with a pint of water, and repeat the wafhing three times, as before directed.

Great care is to be taken, in decanting both the acid and wafhings into the fecond bafon, that none of the copper goes along with them, and left any fhould, they ought to ftand for half an hour in the fecond bafon, and be decanted from it alfo with care, and if any copper is

found at the bottom, it is to be washed and added to the rest.

The copper is now to be dried and weighed, and gives the proportion contained in the ore.

*Observations on the above process.*

It is about twenty years ago that I contrived some methods of assaying ores, which might avoid tedious and troublesome roastings and fusions in great degrees of heat, which require a dexterity which is only to be acquired by great practice, and which after all form a process that is often various in the result, and seldom shews the substances contained in the ore, excepting the metal. The principles on which these processes depend, as far as regards copper ores, are,

First, Metals are attracted more strongly by acids than by sulphur, with which they are often combined in their ores. In consequence, if a metal be combined with sulphur in an ore, it may be separated by applying an acid, which will unite with the metal, and separate the sulphur. The metal may generally be separated from the acid in its metallic form by means of another metal, which attracts the acid more strongly.

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Secondly,

Secondly, Arsenic unites with vitriolic, nitrous, and muriatic acids, forming a corrosion or compound not soluble in water; whereas most other metals may be united with one of these acids, or a mixture of them, so as to form a compound soluble in water: therefore, if there be arsenic combined with a metal in an ore, if it be dissolved in such acid diluted with water, the arsenic will fall to the bottom in a white powder or crystals, and the solution being poured off will contain the metal, which may be separated from the acid by another metal as before.

Thirdly, the calces of metals may be dissolved in acids, whether they be pure (of which there are few instances in ores) or combined with gas, respirable air, or other vapours; therefore, if the metal in an ore be in the form of a calx, we may find an acid which will dissolve it, and we may afterwards precipitate it in its metallic form as before.

Fourthly, When an ore is to be assayed, it should be separated from the quartz, spars, and other earthy matters, with which it is often mixed, as perfectly as possible; however, after all our care there will be often a part of them so intimately mixed with the ore, that it cannot be entirely cleared. Many of these earthy matters do not dissolve readily in acids: therefore, if the metal of an  
ore

ore be dissolved in an acid, so as to form a compound soluble in water, the solution of the metal may be poured off, leaving such earthy matters behind.

Fifthly, If the earthy matter should dissolve in the acid, it is seldom to be precipitated by a metal: therefore if both earth and metal be dissolved, on the application of another metal, which attracts the acid more strongly, that which was combined with the acid will be precipitated, and the earth left in the solution.

Sixthly, Acids attract the metals with different powers: therefore, if two metals be combined with an acid, if we apply to the solution a mass of that which attracts the acid strongest, the other will be precipitated. The mass being weighed before and after the precipitation, the difference will be the quantity of additional metal dissolved; if, therefore, we pour off the liquid from the precipitate, and apply another metal, which attracts the acid still more strongly, the second metal will be precipitated, which being weighed, and the weight lost from the mass deducted, gives the weight of the second metal. As this principle is of great use in investigating the elements of mixed metals, we shall give an example. Suppose copper and silver mixed; dissolve the whole in pure nitrous acid, properly diluted with water; apply to the solution a mass of copper, the silver will be precipitated.

Pour off the solution, and wash the silver and undissolved copper with water; pour the washings into the solution; weigh the mass of copper left, and mark what it has lost; apply to the solution a mass of iron, the whole copper will be precipitated. Pour off the fluid, and wash the precipitate carefully, dry it, and weigh it, deduct the weight lost from the mass of copper, what remains is the weight of the copper in the mixture; if this weight, together with that of the silver, be the weight of the metal originally exposed to examination, there is no reason to suspect any mixture of another metal.

If the metals mixed are unknown, if we can find an acid which will dissolve them, we may try to make a precipitation with the metal which is lowest but one in the order of elective attractions, and so proceed to the next above it, until we come to the highest; and by this means we shall obtain all the metals in the mass.

There are other principles on which I have founded various processes for assaying; but these are sufficient for copper ores, all the different known species of which I have actually assayed, and therefore have ventured to offer this process to the consideration of the Society; first, as only requiring an apparatus which can be bought at any apothecary's or chemist's, and as capable of being performed by a person totally unacquainted with



with chemistry, so that any proprietor of an estate, or his servant, may determine if an ore be of copper, and its value; secondly, as affording an assayer a more perfect manner of determining the value of a copper ore; and, lastly, as a process by which the naturalist may investigate not only the copper in an ore, but its various other contents.

There is but one known species of copper ore in which the copper is not capable of being combined with *aqua regia*, which is blue vitriol, which is sometimes found solid, but more frequently in mineral waters; from this the copper may be precipitated by iron immediately.

We have lately had many opinions published of metals being found in mineral waters combined with various substances. I never examined any mineral water in which I found the metals combined with any other substance but vitriolic acid; and am certain, many authors have been misled by not knowing this property of metallic salts, *viz.* that if we dissolve them in a small proportion of water, or if there be superfluous acid, the solution will remain perfect when exposed to the air; but if the acid be perfectly saturated with the metal, and the proportion of water to the metallic salt be very great, on exposure to the air it is decomposed, the metal precipitating in the form of a calx, and the acid being lost.

This

This may easily be tried by taking common green or blue vitriol, dissolving an ounce in three ounces of water by boiling, letting them stand to cool, and filtering the solution. If this solution be exposed to the air it will remain perfect; but if we drop a drop or two of it into a wine glass full of water, in a few minutes the transparency of the water will begin to be disturbed, and the metal in a short time will fall down, in a red powder if it be iron, in a blue powder if it be copper.

An hundred grains of the ore is sufficient to give the copper contained to one hundred part; if greater accuracy be required 1000 grains may be used.

The mixture of nitrous and muriatic acid is the most proper acid *menstruum* for copper ores, muriatic acid dissolving most readily the calces of metals, and nitrous acid when they are in their metallic form; a metal in its metallic form being a compound of a pure calx and a substance, which has been called inflammable air, but which is an oil found out by STAHL to exist in metals, and which we would call the oil of metals. The nitrous acid decomposes this oil, at the same time that it acts on the calx itself, and leaves it also to be acted upon by the muriatic acid.

When copper is combined with sulphur in an ore, it is in its metallic form; in dissolving in an acid its oil rises  
in

in vapour; or vapours produced by the decomposition of this oil occasion an effervescence.

All the calces of copper I have tried are combined with gas, respirable air, or other vapours, excepting one, which is of a light green colour, brittle, and which breaks smooth like glass; a specimen of it is contained in Dr. HUNTER'S museum: this dissolves without effervescence, the others all effervesce. A boiling heat is necessary to render the solution complete, of which great care is to be taken.

If there be any sulphur in the ore, it appears quite clear in lumps; a small portion of it, however, is destroyed by the nitrous acid. Earthy matters insoluble in acids, if any, and arsenic, appear in a powder at the bottom. If there be any silver it is mixed with this powder, and is to be extracted by melting it with black flux and litharge, and cupelling in the common way. If there be any gold it may be taken out of the solution by æther.

When the copper is combined with nitrous and muriatic acids, it might be thought sufficient to apply the iron immediately; but it is much more convenient to precipitate it from them, and combine it with vitriolic acid, on account of the convenience of washing the precipitate, which is in a more compacted mass.

If

If there be any calcareous earth dissolved, the vitriolic acid will combine with it, and form a white powder, which will be left after the copper is re-dissolved, and must be separated carefully from the solution.

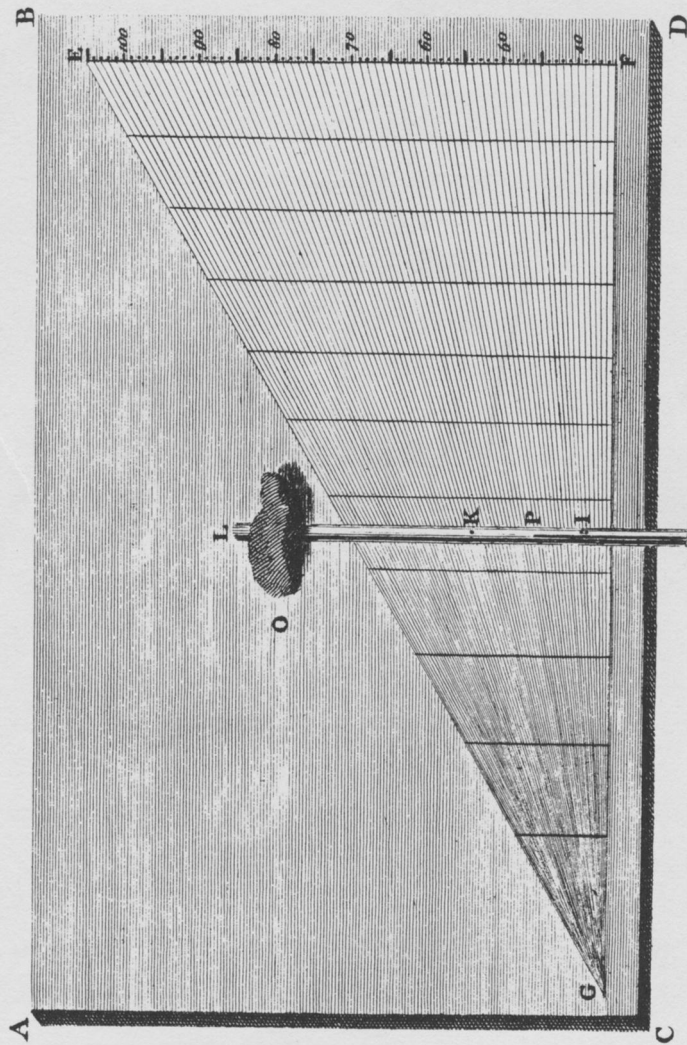
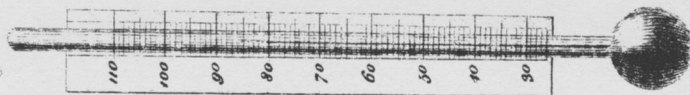
After the precipitation of the copper, it is necessary to get rid of the salts perfectly before we apply the vitriolic acid, otherwise part of the copper would be re-dissolved.

Vitriolic acid will not dissolve copper in its metallic form, and may be applied to dissolve any iron that may be mixed with the precipitate, as well as to loosen copper, which sometimes adheres to the iron.

The solution of the iron must be carefully washed off from the copper.

There is a criterion by which we may judge certainly if any of the copper be lost. Let all the washings and every thing, except the copper, be put into a vessel together; pour in solution of fixed alkali till no further precipitation takes place; let the precipitate subside, and pour off the liquor; apply to the precipitate solution of volatile alkali, sold by the name of spirit of *sal ammoniac*; shake them together, and let them stand for an hour; if the solution of the alkali acquires a purplish blue colour, the process is imperfect, if it does not, it is perfect.

*Fig. 1.*



*Fig. 2.*

